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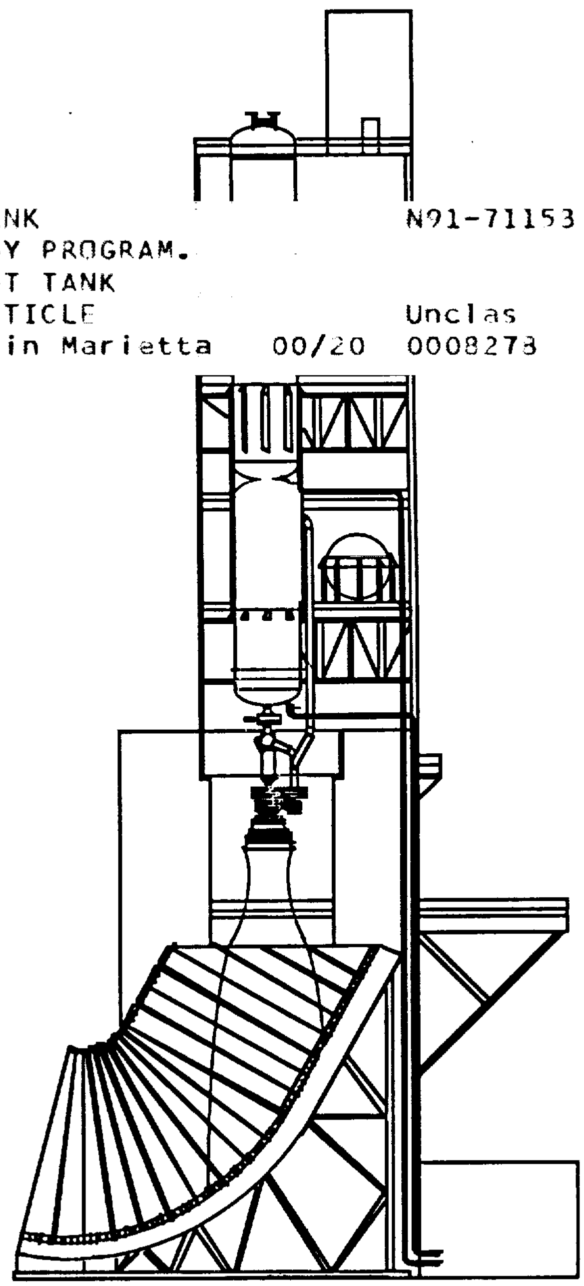
Appendix A
Propellant Tank
Pressurization System
Flight Article
Preliminary Requirements

Propellant Tank Pressurization System Technology Program



(NASA-CR-184146) PROPELLANT TANK PRESSURIZATION SYSTEM TECHNOLOGY PROGRAM. VOLUME 2, APPENDIX A: PROPELLANT TANK PRESSURIZATION SYSTEM FLIGHT ARTICLE PRELIMINARY REQUIREMENTS (Martin Marietta) 00/20

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1.0 Scope: This document identifies the requirements for a flight pressurization system for a large pressure fed booster. The booster may be either liquid, LO_2/RP-1 or hybrid, LO_2/Solid Fuel configuration.

2.0 Applicable Documents. The following documents (all or in part) form a part of this specification.

SPECIFICATIONS

Military

MIL-B-5087 B Amended 2 31 August 1970	Bonding Electrical and Lightning Protection for Aerospace Systems
MIL-E-6051 D Amendment 1 5 July 1968	Electromagnetic Compatibility Requirements, System
MIL-H-5440 G November 28, 1975	Hydraulic Systems, Aircraft, Types I and II, Design and Installation Requirements for,
Mil-I-6870	Nondestructive Inspection Methods
MIL-S-7742 B Amendment 1 15 March 1973	Screw Threads, Standard, Optimum Selected Series, General Specification for
MIL-S-8879 A Amendment 1 15 March 1973	Screw Threads, Controlled Radius Root with Increased Minor Diameter; General Specification for

National Aeronautics and Space Administration

MSC-SPEC-M-1	Identification Specification
MSFC-SPEC-106 B Amendment 1 6 October 1967	Testing Compatibility of Materials for Liquid Oxygen Systems
MSFC-SPEC-494 A April 30,. 1973	Installation of Harness Assembly, (electrical Wiring), Space Vehicle, General Specification
JSC 07636	Lightning Protection Criteria Document
NSTS 07700 Volume X	Space Shuttle Flight and Ground System Specification

NSTS 07700 Volume XII	Integrated Logistics Requirements, Space Program
NSTS 08171	Operations and Maintenance Requirements and Specification Document
NSTS 08800	JSC Supplement to NHB 5300.4 (3A), Requirement for Soldered Electrical Connections
NSTS 20007	Lightning Protection Verification Document
NSTS 22206	?
MSFC-SPEC-250 A 1 October 1977	Protective Finishes for Space Vehicle Structures and Associated Flight Equipment, General Specifications for
MSFC-SPEC-522 A 18 November 1977	Design Criteria for Controlling Stress Corrosion Cracking
SL-E-0001 June 4, 1973	Electromagnetic Compatibility Requirements for the Space Shuttle Program
SL-E-0002 A 16 September 1974	Electromagnetic Interference Characteristics, Requirements for Equipment
SW-E-0002 B January 6, 1976	Ground Support Equipment, Space Shuttle General Design Requirements
SE-F-0044 A February 6, 1975	Filters, Wire Cloth, General Specification
SE-G-0020	Leakage Measurements
SN-P-0006	Double Sided PC Boards, Design Specification for
SE-R-0006	JSC Requirements for Materials and Processes
SE-S-0073 C February 14, 1977	Fluid Procurement and Use Control, Space Shuttle
SN-C-0005 March 6, 1974	Contamination Control Requirements for the Shuttle Program

STANDARDS

<u>Military</u>

MIL-STD-101B	Identification Standards
MIL-STD-105	Sampling Requirements

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MIL-STD-129	Packaging Marking Requirments
MIL-STD-414	Sampling Requirements
MIL-STD-130 F 21 May 1982	Identification Marking of U.S. Military Property
MIL-STD-143 B November 12, 1969	Standards and Specifications, Order of Precedence for the Selection of
MIL-STD-280 A July 7, 1969	Item Levels, Item Exchangeability, Models and Related Terms, Definition of
MIL-STD-454 H June 30, 1982	Electronic Equipment, Standard, General Requirements for
MIL-STD-462 Notices 1 and 2 1 May 1970	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-463 A June 1, 1977	Electromagnetic Interference and Electromagnetic Compatibility Technology, Definitions and System of Units
MIL-STD-810 D July 19, 1983	Environmental Test Methods,
MIL-STD-1247 B 20 December 1968	Markings, Functions, and Hazard Designations of Hose, Pipe, and Tube Lines for Aircraft Missile, and Space Systems
MIL-STD-1472 C May 2, 1981	Human Engineering Design Criteria for Military Systems, Equipment and Facilities

National Aeronautics and Space Administration

MSC-00134	?
MSFC-STD-136	Parts Mounting, Printed Wiring Boards
MSFC-STD-154	Printed Wiring Boards, Specification for
MSFC-STD-506 Dec 15, 1972	Materials and Process Control
JSCM 8080 April 26, 1971	Manned Spacecraft Design Criteria and Standards
20M02540 B Nov. 2, 1979	Assessment of Flexible Lines for Flow Induced Vibration

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OTHER PUBLICATIONS

Handbooks - Military

MIL-HDBK-5 D June 1, 1983	Metallic Materials and Elements for Vehicle Structures
MIL-HDBK-17 A Part I - January 1971 Part II - June 8, 1977	Plastics for Aerospace Vehicles Part I - Reinforced Plastics Part II - Transparent Glazing Materials
MIL-HDBK-23 A December 30, 1968	Structural Sandwich Composites

Handbooks - National Aeronautics and Space Administration

MSFC-HDBBK-505 A January 1981	Structural Strength Program Requirements
KHB 1700.7 A 30 November 1984	Space Transportation System Payload Ground Safety Handbook.
NHB 2254	Methodology for Conduct of NSTS Hazard Analysis
NHB 5300.4 (ID-2) October 1979	Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program
NHB 5300.4 (3A)	Requirements for Soldered Electrical Connectors
NHB 8060.1 February 1974	Flammability, Odor and off Gassing Requirements and Test Procedure for Materials in Environments That Support Combustion.

OTHER PUBLICATIONS

Other Documents - National Aeronautics and Space Administration

NSTS 07700 Volume VII	Commonality Management, Space Shuttle
JSC 09084 October 1974	Coordinate System for the space Shuttle Program
SE-019-043-2H May 20, 1975	Natural Environments for the Space Shuttle Solid Rocket Booster
TM 82473 1982	Terrestrial Environment (Climatic) Guidelines for Use in Aerospace Vehicle Development, 1982 Revision
JSCM 8080.2	JSC Management Instruction

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3.0 Requirements

3.1 Definition

3.1.1 Pressurization System Definition. This specification defines a high pressure, high flow rate, hot gas, propellant pressurization system capable of meeting the oxidizer and fuel flow requirements for large scale hybrid or liquid pressure fed engines.

3.1.2 Mission

3.1.3 Operational Concepts

3.1.4 Organizational and Management Relationships

3.1.5 Systems Engineering Requirements

3.1.6 Government furnished Property

3.1.7 Critical Components

3.1.7.1 Engineering Critical Components List

3.1.7.2 Logistics Critical Components List

3.2 Characteristics

3.2.1 Performance

3.2.1.1 Parallel Operation. The pressurization system shall be capable of operating with two parallel boosters and/or other propulsion systems and satisfy the requirements of this specification, the booster specification in which it is used and the integrated vehicle specification.

3.2.1.2 Propellants.

3.2.1.2.1 Liquid Booster. LO_2 and RP-1 shall be used as propellants for the pressure fed booster flight article.

3.2.1.2.2 Hybrid Booster. LO_2 shall be used as the oxidizer in the hybrid booster.

3.2.1.2.3 Propellant Volume. The total volume of the propellant tanks shall be:

LO_2 tank - 11,700 ft^3

RP-1 tank - 6,700 ft^3

3.2.1.3 Pressure. The system shall be capable of controlling pressure to propellant tanks within ±5% of preset pressure points from 600 to 1350 psia for an ullage volume of 18,000 ft^3.

3.2.1.3.1 Pressurant Storage. The pressurant shall be stored at 40 R and 3000 psia to minimize pressurant weight and volume.

3.2.1.3.2 Pressurization Medium. The pressurization medium shall be helium.

3.2.1.3.3 Pressurant Storage Vessel TBD

3.2.1.4 Flow Rates.

3.2.1.4.1 LO_2. The flow rate for LO_2 shall be 1665 to 7990 lbm. per second. This includes both liquid boosters and hybrid boosters including 50% throttling.

3.2.1.4.2 RP_1. The flow rate for RP_1 shall be 1665 to 3330 lbm. per second.

3.2.1.5 Engine Operation Time. The pressurization system shall accommodate an engine burn time of 120 seconds while satisfying all requirements of section 3.0 of this document.

3.2.1.6 Engine Out Capability. The pressurization system shall be capable of providing necessary pressurization for proper operation of the remaining engines of a multi engine configuration in the event of failure and shutdown of one engine.

3.2.1.6.1 Engine Shut Down The pressurization system shall accommodate engine shutdown on command.

3.2.1.7 Throttling. The pressurization system shall be capable of accommodating the throttling of the engines over the ranges of pressures as defined in paragraph 3.2.1.3 and flow rates as defined in paragraph 3.2.1.4.

3.2.1.8 Loading and Draining. The Pressurization system shall accommodate simultaneous and/or sequential LO_2 and RP-1 loading and/or draining. The system shall have a minimum hold capability, after propellant loading, of seven (7) hours including two (2) minutes pressurized to flight pressurization levels down to T-35 seconds. The design shall not preclude main propellant drain and subsequent reload with no manual operation on the launch pad.

3.2.1.10 LO_2 and Fuel Tank Pressurization. The pressurization system shall accommodate LO_2 and fuel tank prepressurization by ground supplied gas.

3.2.1.11 GO_2 and Fuel Vent and Relief. The pressurizsation system design shall include a system for ground venting during all phases of propellant loading. The system shall be designed to satisfy loading timelines specified in (TBD), loading flow conditions specified in (TBD), and to satisfy propellant conditions required (TBD). In-flight relief and ground relief shall also be provided to maintain tank pressures at a level of no greater than 5% above maximum operating pressure.

3.2.1.12 Propellant Tank Purge. The pressurization system shall accommodate purging of the LO_2 and fuel tanks with helium, nitrogen, or air. Flow shall enter the LO_2 and fuel tanks via the fill, feed, and drain lines and/or the pressurization lines. Flow shall exit the LO_2 and fuel tank via the fill, feed, and drain lines and/or the vent lines.

3.2.1.13 Lines. All lines shall be designed to accept loads resulting from misalignments due to tolerance buildup and structural and thermal deflections. Flexible duct bellow system shall be designed to eliminate or minimize flow induced vibration. All flexible line designs shall be assessed for flow induced vibration per MSFC standard 20M02540. Lines shall be sized for flow velocities to preclude flow induced vibration.

3.2.1.14 Propellant Dump. The pressurization system design shall include provisions for fill, vent, drain, and dump of all liquid propellants.

3.2.1.16 Abort Capability. The pressurization system shall provide a safe mission termination (abort) capability through all mission phases.

3.2.1.17 Notification for Launch. To fulfill the space rescue role, the system shall be capable of launching within 26.5 hours after notification with the flight vehicle mated and ready for transfer to the pad.

3.2.1.18 Launch from Standby. The system shall have the capability to launch the flight vehicle from a standby status within 4 hours. Vehicle access shall be permitted for not less than 45 minutes of consecutive time within the 4 hours. The system shall have the capability to hold in a standby status up to 24 hours.

3.2.1.19 Cryo Loading. The pressurization system shall support the loading of ascent cryogenic propellants within the constraints specified in Paragraph 3.2.1.18. (Launch from Standby). The design shall not preclude main propellant drain and subsequent reload with no manual operations on the launch pad.

3.2.1.20 Cryo Loading Monitor and Control. The Ground System shall be capable of monitoring and remotely controlling flight vehicle functions and parameters critical to propellant loading or draining.

3.2.1.21 Hold After Cryo Loading. The system shall be capable, without recycle, of holding after propellant loading for at least seven hours prior to the initiation of LO_2 drainback. Subsequent to the initiation of LO_2 drainback, a two minute hold capability, with reduction of vehicle performance capability, shall exist until T-31 seconds.

3.2.1.22 On-Time Launch. From initiation of launch activities (beginning of standby through lift-off or from the beginning of the countdown through lift-off) the pressurization system shall be capable of achieving a lift-off with $\pm$ two seconds of the target lift-off time GMT. The two second tolerance shall apply to flight vehicle subsystems only.

3.2.1.23 Prelaunch Purge. The pressurization system shall shall utilize GSE and facilities to meet all purge requirements during the prelaunch phase.

3.2.1.24 On-Pad Abort. The pressurization system shall be capable of recycling to engine start sequence within 24 hours subsequent to an engine shutdown prior to liftoff. Subsequent to an on-pad abort, the system shall have the capability to accomplish the rescheduled design mission without rollback to the VAB.

3.2.1.25 Emergency Power to accomplish Abort. The pressurization system shall have the ability to accommodate the full loss of thrust of one booster engine on each booster and successfully complete an intact abort. Booster engines may be throttled up to emergency power (100%) to accomplish this.

3.2.1.26 Pad Stay Time. The pressurization system shall be capable of remaining on the launch pad for durations up to 180 days. Exposure to natural and induced environments for the pad stay time duration shall not invalidate the design performance or operational capability of the flight vehicle.

3.2.1.26.1 Operational Pad Stay Time. The pressurization system shall be capable of holding on the pad without GSE support for up to TBD days during the operational phase. The operational configuration may be supported by pad access or GSE support during the operations phase in order to hold on the pad for up to TBD calendar days.

3.2.1.27 24-Hour Scrub/Turnaround. The system shall be capable of launching within 24 hours after scrubbing a launch attempt.

3.2.1.28 Launch Recycle. The pressurization system shall be capable of recycling to a TBD time before launch in the countdown, in the event of an SSME shutdown prior to ignition.

3.2.1.29 Automatic Control Override. Crew override capability shall be combined with appropriate caution, warning and system status displays to allow the flight crew to override automatic operations of the pressurization system where hazardous conditions would otherwise result, such as abort initiation.

3.2.1.30 General. The flight article pressurization system shall comply with all applicable requirements of NSTS 07700.

3.2.1.31 Maximum Engine Chamber Pressure. TBD

3.2.1.32 LO2/LH2 Helium Heater Requirements TBD

3.2.1.33 Hold Down. The pressurization system shall be capable of maintaining pressure during hold down of the booster prior to launch release.

3.2.1.34 POGO. The vehicle, in all mated and unmated configurations, shall be free of instabilities resulting from dynamic coupling of the structure, propulsion, and flight control subsystems during all phases of powered flight with all payload variations. Consideration will be given to stability margins, POGO suppression devices, OMS, Boosters and main engine dynamic characteristics, the vehicle flight control subsystem, and appropriate parameter variations of these interacting subsystems. The total coupled system shall be stable for any allowable combination of system parameter variations.

3.2.2 Physical

3.2.2.1 Volume. The pressurization system shall be sized to meet the physical dimensions of the vehicle in which it is used. The minimum vehicle diameter in which the pressurization system shall be used is TBD ft.

3.2.2.2 Component Weight. Weight of all component and subsystems shall be held to a minimum, consistent with the use of high strength to weight ratio materials and within the requirements of reliability goals and structural integrity in the environment specified.

3.2.2.3 Structure. The pressurization system structure, including pressure vessels and mechanical systems, shall have adequate strength and stiffness, at the design temperature, to withstand limit loads and pressures without loss of operational capability for the life of the vehicle and to withstand ultimate loads and pressures at design temperature without failure. The structure shall not be designed to withstand loads, pressures, or temperatures arising from malfunctions that prevent a successful abort.

3.2.3 Reliability

3.2.3.1 Man Rating. The pressurization system shall comply with all man rated requirements defined in NSTS 07700 Vol X.

3.2.3.1.1 Manned Spacecraft Criteria and Standards. The pressurization system flight and ground systems shall conform to the requirements of JSCM 8080 Standards.

3.2.3.2 Flight Vehicle Subsystem Functional Reliability. The redundancy requirements for all flight vehicle systems (except primary structure, thermal protection system, and pressure vessels) shall be established on an individual subsystem basis, but shall not be less than fail-safe. The pressurization system shall meet the reliability requirements specified in NHB 5300.4 (1D-2). Any Deviation/Waiver of reliability requirements shall be in accordance with NSTS 22206.

In addition to Criticality 1 single failure points, the items during intact aborts not meeting the fail safe redundancy requirements shall be identified in the Critical Items List.

This fail safe requirement does not apply to the premature firing failure mode of pyrotechnical devices and functional systems, except associated avionics and circuity. The booster shall be relieved of the fail safe operational requirements when a shutdown is prevented by vehicle applied shutdown inhibit command.

3.2.3.3 Redundancy Verification. Redundant functional paths or subsystems shall be designed so that their operational status can be verified during ground operations without removal of Line Replaceable Unit (LRUs). In addition, these redundant functional paths of subsystems shall be designed so that their operational status can be verified in flight to the maximum extent possible, but as a minimum shall provide capability for redundancy management in the event of a malfunction of a functional path and shall provide information regarding redundancy status of the affected system sufficient to determine if a failure has occurred and if an abort decision is required. Exceptions to the inflight verification requirement of redundant functional paths include:

a. Standby redundancy (redundant paths where only one path is operational at any given time).

b. All functional paths of any subsystem which is inoperative (during such inoperative periods).

c. Mechanical Linkage

Critical redundant items whose failure cannot be detected during normal ground operations or during flight shall be identified in the Critical Items List. Redundancies within a functional path shall be so designed that their operational status can be verified prior to each installation into the vehicle.

3.2.3.4 Quality Assurance. Pressurization system quality shall be in accordance with NHB 5300.4(1D-2).

3.2.3.5 Inspection Requirements. Nondestructive inspection requirements for materials and parts shall be in accordance with MIL-I-6870.

3.2.3.6 Sampling Requirements. Sampling requirements shall be in accordance with MIL-STD-105 and MIL-STD-414.

3.2.3.7 He and N2 Leakage Measurement. Leakage measurement of helium and nitrogen test gases shall be in accordance with MSC SE-G-0020.

3.2.4 Maintainability. The pressurization system shall meet the maintainability requirements provided for in NSTS 07700 Volume XII and NHB 5300.4 (1D-2).1.

3.2.4.1 Servicing. The subsystems shall be capable of being serviced without a permanent fluid attachment to the launch pad.

3.2.5 Operational Availability

3.2.5.1 Useful Life. Useful life for pressurization system shall be TBD.

3.2.6 Safety

3.2.6.1 Safety. The pressurization system safety shall be in accordance with NHB 5300.4.

3.2.6.2 Safing. The pressurization system shall be capable of being safed following an on pad abort.

3.2.6.3 Equipment Design. Equipment design shall not degrade the inherent safety of the equipment under tests. A failure in the equipment shall not injure or create a hazardous condition to personnel, propagate a failure sequentially in associated equipment to damage or degrade the flight vehicle. Equipment shall be designed to include the following safety considerations as a minimum:

a. Maintain operating and overrun temperature below ignition temperature of associated hazardous materials.

b. Hermetically seal, explosion proof, or purge all electrically active items during fueling operations.

c. Provisions for adequate relief valve(s) on equipment and purged enclosures.

d. Loads imposed on the system shall not exceed flight loads.

e. All purge, desiccant, pressurization, etc., equipment required to maintain the system during transport operations shall contain adequate relief valve(s).

f. Provisions to prevent gas, fluid, or material ignition at umbilical connector and coupling interfaces.

g. Venting of hazardous or toxic gases into a collection system for safe disposal

h. Proper identification, marking, and control of sequences to prevent reversal of mismatching of fittings, coupling, electrical connectors, etc.

i. Filtering and contamination control shall be compatible with the flight systems.

j. Provide electrical/electronic equipment with adequate fusing and/or current limiting devices to minimize fire hazards and hardware damage to either ground or flight systems.

3.2.6.5 Separation of Critical Functions. Alternate or redundant means of performing a critical function shall be physically separated or protected such that an event which causes the loss of one means of performing the functions will not result in the loss of alternate or redundant means. Any Deviation/Waiver to requirements for physical separation of critical functions shall be in accordance with NSTS 22206.

3.2.6.5.1 Isolation of Hazardous Conditions. Provisions shall be made to physically isolate or separate hazardous, incompatible subsystems, materials, or environments. Designs shall consider space flight hazardous conditions identified in MSC-00134.

3.2.6.5.1.1 Fasteners. Failure of any single fastener for a line or cable that will cause loss of mission of vehicle will be identified and documented in the Critical Items List (CIL).

3.2.6.5.1.2 Fluid Removal. Capability to permit the removal or purging of all contained fluids shall be provided for all ground operations.

3.2.6.5.1.3 Connectors. System fittings, flanges and fluid connectors shall be keyed or restricted so that it is physically impossible to connect an incompatible component, commodity or pressure level.

3.2.6.5.1.4 Draining. The design of the pressurization system shall not restrict gas ullage inflow to the extent that it will cause collapse or other degradation of the pressure vessels when liquid is drained at the maximum permissible rate.

3.2.6.5.1.5 LRUs. The pressurization system shall be designed so that it is physically impossible to install LRUs in a position or configuration other than that in which it is intended to function.

3.2.6.5.1.6 Propellants Vents. Separate lines and systems shall be used to vent each propellant system.

3.2.6.5.1.7 Pressure Controls. All adjustable pressure control devices shall have prominent markings to indicate the direction of pressure increase/decrease adjustment.

3.2.6.5.1.8 Protection of Critical Functions. The pressurization system shall be designed to prevent inadvertent or accidental activation or deactivation of safety-critical functions or equipment, which would be hazardous to personnel or vehicles during flight and ground operations.

3.2.6.6 Protection of Redundant Components. Redundant components susceptible to similar contamination or environmental failure causes such as shock, vibration, acceleration, or heat loads shall be physically oriented or separated to reduce the chance of multiple failure from the same cause(s).

3.2.6.7 Isolation of Subsystem Anomalies. Isolation of anomalies of critical functions shall be provided such that a faulty subsystem element can be deactivated either automatically or manually without disrupting or interrupting alternate or redundant functional paths or functions of other subsystems which would cause a Criticality 1 or 2 condition. During ground operations, capability to fault-isolate critical functions to the line replacement unit or group of units, without disconnections or use of carry-on equipment, shall be provided.

3.2.6.8 Hazard Analysis. A comprehensive hazard analysis shall be conducted in accordance with NHB 2254 "Methodology for Conduct of NSTS Hazard Analysis" to identify and eliminate hazards in the system design.

3.2.6.8.1 Hazard Reduction Precedence Sequence. Hazard elimination or control during all phases of the pressurization system life cycle shall be accomplished in the following order of precedence:

3.2.6.8.1.1 Design for Minimum Hazard. The major goal throughout the design phase shall be to insure inherent safety to the extent possible through the selection of appropriate design features such as fail operational/fail safe combinations and appropriate safety factors. Hazards shall be eliminated by design if possible, or, where complete elimination is impossible, shall be reduced to the lowest practical level of risk through design. Damage control, containment and isolation of potential hazards shall be included in design considerations. Safety checklists, consisting of lessons learned on prior programs and compendia of safe design practices, shall be used to evaluate designs for safety and to require changes where warranted.

3.2.6.8.1.2 Safety Devices. Known hazards which cannot be eliminated through design selection shall be reduced to a minimum acceptable level through the use of appropriate safety devices as part of the system, subsystem, or equipment. Such safety devices shall conform to the same standards of reliability and quality as the systems with which they are associated.

3.2.6.8.1.3 Warning Devices. Where it is not possible to preclude the existence or occurrence of a known hazard, devices shall be employed for the timely detection of the condition, or the potential for creation of such condition due to operator input, and the generation of an adequate warning signal. Warning signals and their application shall be designed to minimize the probability of wrong signals, misinterpretation of the warning, or of improper or inappropriate personnel reaction to the signal.

3.2.6.8.1.4 Special Procedures. Where it is not possible to reduce the magnitude of existing or potential hazard through design or the use of safety and warning devices, special procedures shall be developed to counter hazardous conditions for enhancement of ground and flight crew safety. Personnel training programs shall be conducted as necessary to inform operations personnel of the nature of the hazard, and in the proper use of the specified procedure in controlling it. Precautionary notations shall be standardized. Hazard reduction by procedure shall include necessary and appropriate controls for verification and approval of the procedural document prior to implementation, and controls and methods for verification that personnel activity does, in fact, follow the procedural document.

3.2.6.8.1.5 Safety Equipment. Where the existence of a hazard is inherent in a procedure and operation, and all of the aforementioned hazard reduction steps do not control the hazard to an acceptable level of risk, safety equipment shall be used to protect personnel or equipment. Training shall be conducted as necessary to insure that such safety equipment is used correctly to control the hazard.

3.2.6.9 Flight System Safety.

3.2.6.9.1 Safety Design Preferences. The pressurization system shall, in the following order of preference, be designed to eliminate hazards by appropriate design measures; or prevent hazards through use of safety devices or features; or control hazards through use of warning devices, special procedures, and emergency protection subsystems.

3.2.6.9.2 Materials. Pressurization system materials shall be selected with characteristics which do not present hazards to personnel or equipment in their intended use or environment.

3.2.6.9.4 Purging, Venting, Drainage, Detection. Provisions shall be made to prevent hazardous accumulations of gases or liquids in the flight pressurization system (i.e., toxic, explosive, flammable or corrosive). Detection of hazardous gases shall be required in critical areas and closed compartments during ground operations, even where ground supplied purge is provided, to insure no hazardous conditions exist. A redundant/alternate hazardous gas detection capability shall be required to prevent a launch delay or a launch scrub, if the primary hazardous gas detection system is lost.

3.2.6.9.5 Protection of Critical Functions. Flight pressurization system subsystems shall be designed to prevent inadvertent or accidental activation or deactivation of safety-critical functions or equipment, which would be hazardous to personnel or vehicles during flight and ground operations.

3.2.6.9.6 Flammable Gas Concentration Limit. The flight pressurization system shall be designed to preclude the concentration of flammable gases in critical areas and closed compartments from exceeding the lower flammable limit for the combination of gases that may be present in areas or compartments for prelaunch, flight, and postlanding operations. Specific prelaunch redlines shall be established to ensure hazardous concentrations are not exceeded in flight. The capability shall be provided for a hazardous gas detection system which is capable of periodic sampling of concentrations of hydrogen, hydrocarbons, and oxygen.

3.2.7 Environment

3.2.7.1 Natural Environments. The pressurization system shall be designed to withstand (or be protected from) all natural environments defined in SE-019-043-2H and NSTS 07700, Volume X, Appendix 10.10 and NASA TM 82473, 1982 Revision.

3.2.7.2 Induced Environments. The pressurization system shall be capable of withstanding the incurred environment imposed during transportation, ground operations, and flight operations as defined in NSTS 07700, Volume X, Appendix 10.11.

3.2.7.3 General. The pressurization system shall be designed to withstand or be protected from moisture, dust, and vermin.

3.2.7.4 Vibro Acoustics The vibro acoustic environments applied to the pressurization system shall be no more severe than current NSTS specifications

3.2.7.5 Base Heating The base heating environments applied to the pressurization sytem shall be no more severe than current NSTS specifications.

3.2.7.6 Lightning Protection. The Pressurization system and elements thereof shall be designed and tested in accordance with NSTS 07636. NSTS 20007 is to be used for verification that the vehicle design meets the requirements criteria document NSTS 07636, and specifically identifies the analysis and test methods to be used for new and existing equipment.

3.2.8 Transportability/Transportation

3.2.9 Storage. The Pressurization system hardware shall be designed for a storage life in accordance with the storage requirments defined in the respective component end item specifications, except that in those cases where age-sensitive materials cannot be avoided, replacement of such materials shall be permitted on a scheduled basis during the storage period.

3.2.10 Operations and Maintenance Requirements and Specifications.

3.2.10.1 OMRS. The Operations and Maintenance Requirements and Specifications for the pressurization system are specified in NSTS 08171.

3.3 Design and Construction Standards

3.3.1 Selection of Specifications and Standards. Specifications and standards for use in the design and construction of the Pressurization system shall be selected in accordance with MIL-STD-143, except that NASA documents, where specified shall take precedence.

3.3.1.1 Design Criteria and Standards. Pressurization system Flight and Ground Systems shall conform to the individual standards of JSCM 8080 identified in Table 2.0 of the basic Volume X. The project office will provide a plan describing the method and extent of implementation of each of the standards to the SSPO for information. Whenever equivalent standards exist at other NASA Centers the element project office may specify these other standards as an alternative. Policy relative to the method and extent of implementation of each of the standards towards GFE used with the Pressurization system is provided by JSC Management Instruction 8080.2.

3.3.1.2 Commonality. The design of the Pressurization system shall provide for maximum efficiency of equipment selection and/or development through multiple applications of common items. Common items and their applications shall be identified, selected and implemented in accordance with the commonality requirements of NSTS 07700, Volume VII, Commonality Management.

3.3.2 Materials, Parts and Processes.

3.3.2.1 Materials and Processes. Materials and processes, except those for new GSE, shall be selected in accordance with MSFC-STD-506. GSE covered by MSFC-STD-506 shall be limited to only that equipment which enters the vehicle or to equipment where GSE hazardous fluid/gas materials compatibility or induced contaminations can adversely affect flight hardware. New ground support equipment to be utilized in the Space Shuttle Program shall be designed in accordance with NSTS SW-E-0002.

3.3.3 Parts Selection. EEE, mechanical, and fluid parts shall be selected from the applicable element project parts list.

3.3.3.1 LO_2 Compatibility. Any material used internally in a liquid oxygen system of the pressurization system shall be LO_2 compatible as determined by NHB 8060.1 and MSFC-SPEC-106.

3.3.5 Electrical

3.3.5.1 Soldering. Soldering of electrical connectors shall be in accordance with NHB 5300.4 (3A), as supplemented by JSC 08800.

3.3.5.2 Circuit Boards. Single and double sided printed wiring board assemblies shall be designed, documented, and fabricated in accordance with MSFC-STD-154. Multilayer printed wiring board assemblies shall be designed and documented in accordance with NSTS Specification SN-P-0006. The fabrication of multilayer printed wiring board assemblies for flight hardware only shall be controlled by NSTS Specification SN-P-0006. Parts mounting design requirements for all types of printer wiring board assemblies shall be in accordance with MSFC-STD-136. GSE is excluded from this requirement.

3.3.5.3 Electrical Bonding. Electrical bonding shall be in accordance with MIL-B-5087 in all areas, except in the area of lightning protection where the requirements of NSTS 07636 shall apply.

3.3.5.4 Electromagnetic Compatibility. The Pressurization system and elements thereof including payloads, shall be designed and tested in accordance with NSTS SL-E-0001, Specification, Electromagnetic Compatibility Requirements, Systems for the Space Shuttle Program. Subsystem and/or individual equipment shall be designed and tested in accordance with the following documents:

a. NSTS SL-E-0002, Specification Electromagnetic Interference Characteristics, Requirements for Equipment, for the Space Shuttle Program.

b. MIL-STD 462, Electromagnetic Interference Characteristics, Measurement of.

c. MIL-STD-463, Definition and System of Units, Electromagnetic Interference Technology.

d. The overall engine system shall be designed to meet requirements of MIL-E-6051.

The subsystem and/or individual equipment requirements are not applicable to ground system procurements unless specifically required by the procuring activity to meet the requirements for EMI critical equipment as defined in NSTS SL-E-0001.

3.3.5.5 Wire and Cable Installation. Wire and harness installation shall be designed so as to minimize potential damage. Wiring shall be protected by easily removable covers or other protective devices. Wiring shall be installed per MSFC-SPEC-494.

3.3.6 Mechanical

3.3.6.1 Definitions. For the purpose of interpretation of this section, the following definitions will apply:

a. Limit Load. The maximum load expected on the structure during mission operation, including intact abort.

b. Ultimate Factor of Safety. The factor by which the limit load is multiplied to obtain the ultimate load.

c. Ultimate Load. The product of the limit load multiplied by the ultimate factor of safety.

d. Allowable Load. The maximum load which the structure can withstand without rupture or collapse.

e. Maximum Operating Pressure. The maximum pressure applied to the pressure vessel by the pressurizing system with the pressure regulators and relief valves at their upper limit, with the maximum regulator fluid flow rate, and including the effects of system environment such as vehicle acceleration and pressure transients.

f. Proof Pressure. The pressure to which production pressure vessels are subjected to fulfill the acceptance requirements of the customer, in order to give evidence of satisfactory workmanship and material quality. Proof pressure is the product of maximum operating pressure times the proof factor.

g. Margin of Safety. The ratio of allowable load to ultimate load minus one.

h. Safe-Life. A design criteria under which failure will not occur because of undetected flaws or damage during the specified service life of the vehicle; also, the period of time for which the integrity of the structure can be ensured in the expected operating environments.

3.3.6.2 Design Safety Factors. The factors of safety given in Table II shall be used for the pressurization system. Proof factors developed from fracture analyses are shown in Table (TBD).

3.3.6.3 Ultimate Combined Load. The external, thermally induced, and internal pressure loads should be combined in a rational manner according to the equations given in Table II, Note (2) to determine the design loads. Any other loads induced in the structure, e.g., during manufacturing, shall be combined. No load conditions outside the crew safety envelope shall be considered. In no case shall the ratio of the allowable load to the combined limit loads be less than the designated SF. These equations are applicable to either tension or compression loads. All structural components that are subject to compressive inplane stresses, including loads resulting from temperature changes, shall be investigated for buckling failure. The evaluation of buckling strength shall consider the combined action of primary and secondary stresses and their effects on (1) general instability, (2) local or panel instability, (3) crippling, and (4) creep. Design loads for buckling shall be ultimate loads. Loads tending to alleviate buckling shall not be increased by the ultimate factor of safety. Destabilizing limit loads shall be increased by the ultimate factor of safety although stabilizing loads shall not.

TABLE II
DESIGN FACTORS OF SAFETY

COMPONENT	FACTORS OF SAFETY	
	ULTIMATE	YIELD
1. <u>General Structure</u>		
Limit Load		
o Well Defined	1.25	1.10
o Other	1.40	1.10
3. <u>Propulsion System</u>		
(a) Propellant Feed Lines and All Other Lines Greater than 1.5 in. Dia. Whichever is Critical		

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	o Limit Pressure	1.50	1.25
Or	o Limit Load	1.40	1.10
(b)	Lines Less than 1.5 in. Dia.		
	o Limit Pressure	4.0	2.0
(c)	Hydraulic & Pneumatic Lines, High Pressure Vessels, Actuating Cylinders, Valves, Filters, and Switches		
	o Limit Pressure	2.0	1.5

NOTES:

1. Ultimate Factor of Safety application
   Use Factor of Safety = 1.25 for well defined loads.
   Use Factor of Safety = 1.40 for all other loads.
   The equivalent Factor of Safety (Eq. F. S.) is derived by the equation:

$$\text{Eq. F.S.} = \frac{1.25\ (\text{well defined loads}) + 1.40\ (\text{all other loads})}{\text{Total Loads}}$$

   Eq. F.S. must be between the limits 1.25   Eq. F.S.   1.40. Should the Eq. F.S. exceed 1.40, the total limit load will be multiplied by a F.S. 1.40. Should the Eq. F.S. be less than 1.25, the total limit load will be multiplied by F.S. = 1.25.

2. Ultimate Combined Load Equations-Loads induced in the pressurization system structure shall be combined according to the following equations:

   a. K1 (L well defined) + K2 (L thermal) + K3 (L pressure) + K4 (L dynamic)   1.25 L.

   b. K1 = 1.25 for boost conditions when the term is additive to the algebraic sum,   L.

   c. K2 = 1.40 for conditions when the term is additive to the algebraic sum,   L.

   d. K3 - 1.25 for the main propulsion tanks when the term is additive to the algebraic sum,   L.

   e. K4 = 1.40 for aerodynamic loads and dynamic transient loads.

   f. K2, K3 = 1 when the term is subtractive to the algebraic sum,   L.

   g. L well defined = loads due to thrust, inertia from thrust and dead weight.

   h. L thermal = thermally induced loads.

   i. L pressure = maximum expected regulated pressure where additive to the algebraic sum,   L.

J. L pressure = minimum expected regulated pressure when subtractive to algebraic sum, L.

3.3.6.4 Allowable Mechanical Properties. Values for allowable mechanical properties of structural materials in their design environment, e.g. subjected to single or combined stresses, shall be taken from MIL-HDBK-5, MIL-HDBK-17, MIL-HDBK-23, or other sources approved by NASA. Where values for mechanical properties of new materials or joints or existing materials or joints in new environments are not available, they shall be determined by analytical or test methods approved by NASA. Complete documentation of testing and analyses used to establish material properties and design allowables shall be maintained by the contractor, and the documentation shall be made available to the procuring agency on request. When using MIL-HDBK-5, material "A" allowable values shall be used in all applications where failure of a single load path would result in loss of vehicle structural integrity. Material "B" allowable values may be used in redundant structure in which the failure of a component would result in a safe redistribution of applied loads to other load-carrying members.

3.3.6.5 Fracture Control. In addition to the factors of safety presented in 3.3.6.2, designs for primary structure including composite structure, glass components or other subsystems, and tanks shall consider the presence of sharp cracks, crack-like flaws, or other stress concentrations in determining the life of the structure for sustained loads and cyclic loads coupled with environmental effects. Parts determined to be fracture critical, including all pressure vessels, shall be controlled in design, fabrication, test, and operation by a formal, NASA approved, fracture control plan as specified in SE-R-0006, "JSC Requirements for Materials and Processes".

3.3.6.6 Fatigue. Safe life design shall be adopted for all major load carrying structures. These structures shall be capable of surviving without failure, a total number of mission cycles that is a minimum of four times (for low cycle), or ten times (for high cycle) greater than the total number of mission cycles expected in service. (Life cycle requirements in excess of 10,000 cycles are considered high.) This does not preclude fail-safe structural features. For new designs, refer to MSFC-HDBK-505.

3.3.6.6 Creep. The design shall preclude cumulative creep strain leading to rupture, detrimental deformation, or creep buckling of compression members during their service life. Analysis shall be supplemented by test to verify the creep characteristics for the critical combination of loads and temperature.

3.3.6.7 Temperature. The effects of temperature extremes specified in 3.2.7.2 shall be considered in the design of the structure of the pressurization system. Thermal design shall be based on the nominal heating environments. Off-nominal assessments shall be performed and incorporated as a design requirement only when the resultant analysis shows a critical condition exists.

3.3.6.8 Load Conditions. The stresses developed in structural members shall be established and shall be accounted for from all load sources that act in combination at any point in the mission profile, with due regard being given to the probability and simultaneity of the occurrence. Acceptable statistical procedures shall be used in the treatment of load sources having statistical variation.

3.3.6.8.1 Load and Internal Pressure Combination. When internal pressure effects in combined load conditions are stabilizing or otherwise beneficial to structural load capability, the minimum limit internal operating pressure or minimum regulated pressure for that condition shall be used for design instead of the ultimate internal pressure.

3.3.6.9 Aeroelasticity. Static and dynamic structural deformations and responses including the effects of aeroelasticity under all limit conditions and environments shall be accounted for in the design of the pressurization system and shall not cause a system malfunction, preclude the stable control of the vehicle, or cause unintentional contact between adjacent bodies.

3.3.6.10 Stress Concentration. Appropriate stress concentration factors shall be applied in stress analysis.

3.3.6.11 Misalignment and Tolerances. The effects of allowable structural misalignments, control misalignments, and other permissible and expected dimensional tolerances shall be considered in the analysis of all loads, load distributions, and structural accuracy. For establishing allowable stresses and critical design stresses, a statistical combination of design tolerances shall be used.

3.3.6.12 Design Thickness. Stress calculations of structural members, critical for stability, shall use the mean drawing thickness or 1.05 times the minimum drawing thickness, whichever is less. Structural members, critical for strength, shall use the mean drawing thickness or 1.10 times the minimum drawing thickness, whichever is less. The wall thickness used in the stress calculations for pressure vessels shall be the minimum thickness shown on the drawing. The thickness for tension-critical and shear critical members shall be the minimum thickness. External panels shall be free of panel flutter at 1.5 times the local dynamic pressure at the appropriate temperature and mach number for all flight regimes including aborts.

3.3.6.13 Strength and Stiffness. The pressurization system structure, including pressure vessels and mechanical systems, shall have adequate strength and stiffness, at the design temperature, to withstand limit loads and pressures without loss of operational capability for the life of the vehicle and to withstand ultimate loads and pressures at design temperature without failure. The structure shall not be designed to withstand loads, pressures, or temperatures arising from malfunctions that prevent a successful abort. Major structural elements shall not be designed by nonflight conditions, i.e. conditions other than prelaunch (vehicle mating).

3.3.6.14 Pressurization. The pressurization system structural design shall include the effects of differential pressures within/between the components due to operational activities of ascent, separation, and reentry, as defined in 3.2.7.2.

3.3.6.15 Venting. Venting shall be provided in the pressurization system components to ensure that internal limit pressures are not exceeded. Venting shall also be provided in the pressurization system components and/or their shipping containers or pressure test fixtures to assure that the components will experience no external collapsing pressures during transportation or testing. The appropriate vehicle cavities shall be vented to maintain a pressure differential which will not be detrimental to flight hardware.

3.3.6.16 Drainage. Where required, provisions shall be made in the structure to drain accumulated liquids, e.g. condensation, rainwater, or spills. The system shall provide for collection for disposal of drained hazardous materials.

3.3.6.17 Purging and Flushing. System design shall provide for purging/flushing of all plumbing and fluid components. Components which cannot be designed to satisfy this requirement shall be identified and shall use quick-disconnect mechanical and electrical interfaces to allow local flushing or removal for flushing.

3.3.6.18 Hazardous Gases. Provisions shall be made to prevent the accumulation of hazardous, i.e. toxic, explosive, flammable, or corrosive, gases and/or fluids in the pressurization system. In closed volumes, including those that are purged, where there is a significant risk of hazardous gas accumulation, detection of hazardous gases shall be provided by means of sensing lines to the GSE analyzer to ensure that hazardous conditions do not exist during prelaunch and flight.

3.3.6.19 Leak Protection - External Ports. Servicing and test ports, not required to function in flight, shall be designed to preclude leakage in flight. If caps are used, the material shall be compatible with the applicable subsystem media and the expected environments.

3.3.6.20 Hydraulic Systems. Hydraulic systems design shall be in accordance with MIL-H-5440.

3.3.6.21 Flow Induced Vibration. All flexible lines and bellows shall be analyzed and designed to exclude or minimize flow induced vibrations in accordance with 20M02540.

3.3.6.22 Improper and/or Cross Connection Prevention. Fluid lines, fasteners, sockets, and like items shall be designed to preclude inadvertent interchanging of connection.

3.3.8 Materials. All materials shall be selected in accordance with the Materials and Processes Control Plan to insure that materials characteristics do not present hazards to personnel or equipment in their intended use or environment.

3.3.8.1 Hazardous Materials and Components. Hazardous materials and components (i.e., fuels, oxidizers, pyrotechnic devices) shall be transported, stored, used, handled, and maintained in a manner that will not constitute a hazard to personnel, the flight vehicle, equipment, payloads, the environment, and/or the mission.

3.3.8.2 Screw Threads. Screw threads for threaded fasteners used on Pressurization system hardware shall be of unified thread form in accordance with MIL-S-7742 or MIL-S-8879, as applicable:

a. Material strength levels up to, but not including 160 KSI may be threaded per MIL-S-7742 or MIL-S-8879. Rolled threads are preferred.

b. Material strength levels 160 KSI and above shall be threaded per MIL-S-8879. Any rolling of external threads, when required, shall be done after heat treatment.

Screw threads used on airborne fluid systems fitting shall be of unified thread form, Class 3 in accordance with MIL-S-7742 or MIL-S-8879.

3.3.9 Contamination Control. Contamination of the pressurization system shall be controlled to assure system safety, performance, and reliability. Control shall be implemented by a coordinated program in accordance with SN-C-0005 from design concept through procurement, fabrication, assembly, test, storage, delivery, operations, and maintenance of the pressurization system.

Selection of the system design shall include consideration of materials compatibility, corrosion resistance, and sensitivity to contamination. Fluid systems design shall include self-cleaning (filtering) protection compatible with component sensitivity.

Wire cloth filters used in the flight pressurization system and at the flight systems/GSE interface shall conform to SE-F-0044.

Specific cleanliness levels in accordance with SN-C-0005 shall be established for materials surfaces, fluid systems, and functional items, as required for effective control of contamination.

Fluids required for manufacture, test, cleanliness evaluation, and operation of the pressurization system shall meet the purity, cleanliness, and analysis requirements of SE-S-0073. Design of the pressurization system structures and components shall minimize the necessity for special cleaning techniques, or hand cleaning during rework or modification operations.

3.3.9.1 Moisture and Fungus Resistance.

3.3.9.1.1 Moisture. The pressurization system structure shall provide moisture proof enclosures, as required, for the recovery, electrical, and instrumentation subsystems. All TPS material and installation design shall minimize absorption and entrapment of liquids or gases which would degrade thermal or physical performance or present a fire hazard (wicking), and shall not require draining, drying, or any dedicated purge system from installation through launch.

3.3.9.1.2 Fungus. Materials which are nonnutrient to the fungi defined in MIL-STD-810, Method 508, shall be used. When fungus nutrient materials must be used, they should be hermetically sealed or treated to prevent fungus growth for the effective lifetime of the component. Materials not meeting this requirement shall be identified as a limited life component and shall identify any action required such as inspection, maintenance, or replacement periods. Fungus treatment shall not adversely affect unit performance or service life. Materials so treated should be protected from moisture or other

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environments that would be sufficient to leach out the protective agent. Fungus inert materials are listed in MIL-STD-454, Requirement No. 4.

3.3.9.1.3 Moisture and Fungus Resistant Treatment. Electrical, electronic and communications equipment shall be treated for moisture and fungus in accordance with requirements specified in Paragraph 3.3.9.1

3.3.9.2 Corrosion of Metal Parts.

3.3.9.2.1 Stress Corrosion. MSFC-SPEC-522 shall be used for design and materials selection for controlling stress corrosion cracking. Metals susceptible to stress corrosion cracking in the environmental of service conditions defined herein, shall not be used unless test data are furnished which indicate material suitability.

3.3.9.2.2 Corrosion Protection. Corrosion resistant metals shall be used wherever cost effective and practical. The use of dissimilar metals, finishes, and coating shall comply with the requirements of MSFC-SPEC-250.

3.3.10 Coordinate Systems. Coordinate systems shall be in accordance with JSC-09084.

3.3.11 Interchaneability and Replaceability. The definitions of item levels, item exchangeability, models and related items, shall be in accordance with MIL-STD-280.

3.3.11.1 Line Replaceable Units. All LRUs which possess the same functional and physical characteristics as to be equivalent in performance, reliability, and maintainability shall be interchangeable.

3.3.11.2 Shop Replaceable Units. All shop replaceable units (SRUs) which possess the same functional and physical characteristics as to be equivalent in performance, reliability, and maintainability shall be interchangeable.

3.3.12 Identification and Marking

3.3.12.1 Identification and Marking. The identification and marking of Pressurization system equipment shall be in accordance with MIL-STD-130, except that the "design activity code", manufacturer's trademark" and "licensor code identification", need not be combined with the part number when marking parts and assemblies. The identification and marking of GFE furnished by JSC may be in accordance with MIL-STD-130 or MSC-SPEC-M-1. Pipe, hose and tube lines of flight vehicles only shall be marked in accordance with MIL-STD-1247. Ground Support Equipment fluid lines and compressed gas cylinders shall be marked in accordance with MIL-STD-101. Existing GSE/facility piping installed at KSC Launch Complex 36 shall remain as currently identified; this equipment has been identified in accordance with MIL-STD-1247 and shall be treated as a unique case within the National STS Program. New GSE/facility piping required to interface with existing Launch Complex 36 equipment shall be identified in accordance with Space Transportation System Payload Ground Safety Handbook KHB 1700.7 and MIL-STD-101B. Direct electro-chemical etched markings may be used when other marking is not feasible. Packing marking requirements shall conform to the requirements of MIL-STD-129.

3.3.12.2 Interface Identification. All interface fluid, gaseous, mechanical and electrical connections (element-to-element, element-to-payload, ground-to-flight) will be identified in a manner to provide ease of viewing, with and without GSE installed, with the flight element in either horizontal or vertical position.

3.3.12.3 Element Cosmetic Coatings. Cosmetic requirements for all pressurization system elements shall be restricted to appropriate markings or decals, as necessary. Priority consideration shall be given to weight and thermal performance.

3.3.12.4 Traceability. Traceability shall be provided by assigning a traceability identification to the pressurization system and providing a means of correlating each to its historical records, and conversely, the records must be traceable to each pressurization system. Ground operations system traceability requirements shall be in accordance with the requirements of Paragraph 3.4.15 of Space Shuttle Ground Support Equipment General Design Requirements, SW-E-0002.

3.3.12.4.1 Traceability Classification. Traceability classification is the classification of a raw material, part, assembly, or end item for determining the traceability marking and traceability records required or excluded for the item. Engineering Documentation (e.g., specifications and drawings) shall specify traceability for items in accordance with the following:

a. Serial Traceability (TS) - Hardware assemblies and components down to and including the Line Replaceable Unit (LRU) level, shall be traceable by serial where one or more of the following apply:

1. The item is contained in the Critical Items List (CIL)

2. The item has a limited useful life

3. The item is to be subjected to acceptance induced environmental test (thermal and/or vibration)

4. The item requires progressive comparative measurements of performance (i.e., transducer curves)

5. The item is subject to fracture control

6. The item contains traceable subordinate units, assemblies, or parts

b. Lot Traceability (TL) - This classification requires lot serial numbering on items produced (manufactured, processed, inspected, or tested by the batch, mix, heat, or melt) in given time sequence, without changes in materials (substitutions); changes in tooling or processes (which would affect form, fit or function);
or substitution of non-certified personnel for those normally requiring certification; and without change in configuration. The

"given time sequence" nominally includes identification of work from the initiation of the production order for specific hardware manufacture, through completion of the last operation on the production order, and therefore includes accumulation of generic data which are related to all items of a particular lot.
Electrical, Electronic, and Electromechanical (EEE) parts specified in "applicable element project parts list," require lot traceability as a minimum.

c. Member Traceability (TM) - Both serial number and lot number traceability shall be required on items which must be identified in such a manner that they can be handled as members of a lot and also controlled as individual items.

d. Exempt from Traceability (E) - All items not falling into one of the previous classifications shall be classified as exempt.

3.3.12.4.2 Traceability Identification. Each item identified as traceable (TS, TL, TM) shall have a traceability identifier consisting of the manufacturer's DOD code identification number and a serial, lot, or member number. The serial, lot, or member number shall be assigned by the manufacturer and shall not exceed ten characters (alphas, numerics, dashes, etc.).

3.3.13 Workmanship. The pressurization system, including all parts and assemblies, shall be designed, constructed, and finished in a quality manner. Defective plating, painting, riveting, machine-screw assembly, welding, brazing, deburring, cleaning, and defective marking of parts and assemblies shall be cause for rejection. Manufacturing practices shall be followed that will produce equipment free of defects.

3.3.14 Human Performance/Human Engineering. Safety related human engineering principles shall be applied during design, development, manufacture, test, maintenance, and operation of the pressurization system and associated equipment, facilities and tooling to minimize tht potential for creation of hazards through human error.

3.3.14.1 Human Engineering Design Criteria. The guidance contained in MIL-STD-1472 shall be applied to the design of the pressurization system and its associated equipment, tooling and facilities.

3.4 Logistics. The logistics requirements and means for providing logistics support shall be as specified in NSTS 07700, Volume XII.

3.4.1 Design for Maintenance. The maintenance concept will be to "remove and replace" to the functional LRU level. "Repair-in-Place" may be accomplished only when justified by the results of the maintenance analysis, associated trade studies, and consideration of impact on requirements.

3.4.1.1 Levels of Maintenance. The three levels of maintenance are:

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Level 1 - Organizational

Organizational maintenance includes preventive and corrective actions required to inspect, service, and clean hardware, and remove and replace defective LRUs. LRUs removed during organizational maintenance are transferred to intermediate or depot level maintenance shops for repair/rebuild. At the organizational level, the maintenance concept is to remove and replace defective LRUs.

Level 2 - Intermediate

Intermediate level maintenance is performed in direct support of organizational maintenance and involves repair of LRUs by the removal and replacement of SRUs.

Level 3 - Depot.

Depot maintenance supports lower levels of maintenance by providing technical assistance and performing maintenance beyond the capability of organizational and intermediate levels. Depot maintenance capability requires equipment, facilities, and/or skills not economically available at organizational and intermediate maintenance levels. Depot level maintenance is performed by designated sources, e.g. manufacturers, NASA centers, and Department of Defense (DOD) depots.,

3.5 Personnel and Training. The design shall consider tasks to be accomplished by operating, test, and maintenance personnel. Considerations should include safety, accessibility, critical tasks, complexity, and necessity for training. Personnel and training requirements are specified in NSTS 07700, Volume XII.

3.6 Interface Requirements

4.0 Verification

4.3 Verification Cross Reference Index

4.4 Test Support Requirements

4.4.1 Facilities and Equipment

5.0 Preparation for Delivery

6.0 Notes

10.0 Appendix